A Comparison of Percutaneous Cryoablations and Percutaneous Radiofrequency Ablations in the Treatment of Renal Cell Carcinoma

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Abstract

Renal cell carcinomas make up two to three percent of all malignancies in adults, and are the cause of over 102,000 deaths worldwide each year (Cohen & McGovern, 2005). It is the most common kidney tumor, and the incidence of renal cell carcinoma is slowly on the rise. Percutaneous radiofrequency ablations and percutaneous cryoablations are becoming an alternative treatment and are a successful treatment option in the fight against renal cell carcinoma (Park, Anderson, & Matsumoto, 2006).

The purpose of this study is to compare the efficacy of percutaneous radiofrequency ablations and percutaneous cryoablations of renal cell carcinoma in terms of the pain associated with each procedure as measured by the amount of intra-operative analgesics required, the amount of post-operative analgesics required; and the length of time required to perform the ablation procedure.

A total of 34 patients over the age of 18 that underwent percutaneous cryoablations or percutaneous radiofrequency ablations were included in this study. Using a Chi-Square test of significance ($p=.05$), no significant relationships were identified in reference to the dose of intra-operative analgesics and post-operative analgesics administration and the type of ablation. However, a significant correlation identified utilizing a Point Bi-serial test of significance comparing the procedure lengths of percutaneous cryoablations and percutaneous radiofrequency ablations.

Chapter 1

Introduction

Percutaneous radiofrequency ablations and cryoablations are a minimally invasive way to treat renal cell carcinomas, and preserve kidney function (Fergany, 2005). Percutaneous radiofrequency ablations are performed by inserting a probe into the tumor site and inducing a high electrical current that heats up the tumor and eventually destroys it. Cryoablative therapies do the exact opposite. Probes are inserted into the tumor and high pressure argon and nitrogen gases are circulated throughout the probes. This allows the core temperature of the tumor to reach as low as -190 degrees Celsius, forming ice crystallization on the tumor which necrosis the tumor (Lehman & Landman, (2), 2008). The probes are then slightly heated, during the thaw cycle, causing the tumor to go through a state of ischemia Lehman & Landman, (2), 2008). Many freeze-thaw cycles are used during cryoablations to insure cell death of the tumor (Fergany, 2005; Lehman & Landman, (2), 2008).

Percutaneous radiofrequency and cryoablative therapies are nephron sparing alternatives for the treatment of renal cell carcinoma. These ablative therapies are appealing to patients who have a solitary kidney, those who are poor surgical risks, immunocompromised patients, and to patients with coagulation problems (Park, Anderson, & Matsumoto, 2006; Permpongkosol, Nielsen, & Solomon, 2006; Lehman & Landman, (2), 2008; Breen, Rutherford, Stedman, et al, 2007). By offering percutaneous ablative treatments, it allows the patients to become surgical candidates as a way to treat their cancer.

Problem Statement

Renal cell carcinoma is the seventh most common cancer in men, and the ninth most common in women in the United States. It is responsible for more than 102,000 deaths a year, and is prevalent in more than 209,000 cancer cases per year. It seems to be more prevalent in males by a ratio of 2:1 (Cohen & McGovern, 2005). The incidence of renal cell carcinoma has been increasing over the years, as well as the mortality rates associated with this disease. Some of the risk factors associated with renal cell carcinoma include smoking, obesity, and hypertension. Signs and symptoms of renal cell carcinoma include hematuria, flank pain, and a palpable abdominal mass. Treatments for renal cell carcinoma include radical nephrectomy, partial nephrectomy, ablations, and chemotherapy (Cohen & McGovern, 2005; Fergany, 2005).

Review of Literature

Renal cell carcinomas make up two to three percent of all malignancies in adults, and are the cause of over 102,000 deaths worldwide each year (Cohen & McGovern, 2005). It is the most common kidney tumor, and the incidence of renal cell carcinoma is slowly on the rise. Treatment of renal cell carcinomas include chemotherapy, radical extirpative surgeries, and more recently, nephron-sparing procedures such as laparoscopic partial nephrectomy, open partial nephrectomy, and percutaneous needle ablative therapies (Cohen & McGovern, 2005; Fergany, 2005). Percutaneous radiofrequency ablations and percutaneous cryoablations are becoming an alternative treatment for patients whose bodies are unable to handle a significant surgery. Percutaneous ablative therapies are a successful treatment option in the fight against renal cell carcinoma, which preserves renal function, as well as decreasing postoperative morbidity, and decreasing the amount of recovery time (Park, Anderson, & Matsumoto, 2006).

Ablative therapies such as radiofrequency ablations and cryoablations are appealing to those patients who have a solitary kidney, those with multiple comorbiditiesm, as well as many immunocompromised patients (Park, Anderson, & Matsumoto, 2006; Permpongkosol, Nielsen, & Solomon, 2006). Tumor ablative procedures significantly reduce the amount of blood loss during a surgery which makes a patient with a history of coagulopathy an immediate candidate (Lehman & Landman, (1), 2008; Breen, Rutherford, Stedman, B., et al, 2007). Percutaneous tumor ablations are being used more frequently in the treatment of small cell renal carcinoma, and primarily focusing on patients with a tumor size of less than four centimeters (Fergany, 2005; Park, Anderson, & Matsumoto, 2006). When tumor size grows larger than four centimeters it becomes very difficult to fully ablate the tumor in one treatment, and multiple treatments are required (Arima, Yamakado, Kinbara, et al., 2007). Tumor location is the primary deciding factor of whether a patient is a good candidate for an ablative procedure (Park, Anderson, & Matsumoto, 2006). Tumors that are situated posterior have the greatest success rate for percutaneous cryoablations and radiofrequency ablations. When the tumor sits anteriorly in the body it becomes difficult to percutaneously ablate the tumor. In such cases the alternative is to execute the procedure laprascopically in fear of injuring a bowel, organ or ureter (Park, Anderson, & Matsumoto, 2006; Breen, Rutherford, Stedman, et al, 2007; Boss, Clasen, Kuczyk, et al., 2007). Exophytic tumors seem to be less complicated to ablate using radiofrequency because the insulation of the fat allows for a higher ablation temperature. Contrarily, it becomes more difficult to ablate tumors that are situated close to large blood vessels using radiofrequency (Boss, Clasen, Kuczyk, et al., 2007). This is due to the fact that there is a great deal of heat dissipation through the blood flow in the vessels, known as the heat-sink effect (Fergany, 2005; Boss, Clasen, Kuczyk, et al., 2007). So, while many patients may be a good candidate for percutaneous ablative procedures due their poor surgical risk, final decisions is based on the tumor size and tumor location.

Percutaneous radiofrequency ablation incorporates the use of a high frequency probe that generates an electrical current (Lehman & Landman, (2), 2008). The probe is placed in the targeted tumor where it delivers a frequency of 400 to 500 kilohertz, which can produce temperatures ranging from 60 degrees Celsius to 110 degrees Celsius (Lehman & Landman, (2), 2008; Breen, Rutherford, Stedman, et al, 2007). It is these excessive temperatures that cause a coagulative necrosis of the tumor (Fergany, 2005; Breen, Rutherford, Stedman, et al, 2007). Contrarily, cryoablation uses the Joule-Thompson effect and circulates high pressure argon or nitrogen gas to achieve temperatures as low as -190 degrees Celsius (Lehman & Landman, (2), 2008). Renal cell carcinomas are destroyed by using freeze-thaw cycles at temperatures ranging from -20 degrees Celsius to -40 degrees Celsius (Fergany, 2005; Lehman & Landman, (2), 2008). This temperature at the core of the tumor is achieved by extending the targeted site of ablation 1 centimeter passed the borders of the tumor (Breen, Rutherford, Stedman, et al, 2007). When the probe is inserted into the tumor it causes a direct toxicity to the cells because of the ice crystallization that the probes form. Once the thaw cycle reaches the tumor, the tumor then goes through a state of ischemia where the blood flow is significantly reduced (Lehman & Landman, (1), 2008). The success of the thaw cycle is based on the cooling rate. As the rate of the cooling cycle increases, so does the production of intracellular ice, which is the destructive element of cryoablations (Lehman & Landman, (2), 2008). Multiple freeze-thaw cycles also seem to be successful at achieving cell death by repeated injury and ischemia to the tissue (Fergany, 2005; Lehman & Landman, (1), 2008).

Tumor location remains of high importance when evaluating a patient for percutaneous ablations. Patients with tumors that are near blood vessels tend to be poor candidates of radiofrequency ablations because of the heat sink effect. Renal cell carcinomas also tend to have a great deal of blood flow themselves, which absorbs the heat from the radiofrequency probe. To make the procedure more successful, many physicians are using a method of renal arterial embolization to reduce blood flow throughout the tumors (Arima, Yamakado, Kinbara, et al., 2007). By doing this, less heat is dissipated which allows the tumor to reach a higher central temperature and provides a better chance of tumor necrosis (Arima, Yamakado, Kinbara, et al., 2007). When performing percutaneous ablations it is also important to be precise with the placement of the probe so that no ureters or other surrounding organs are harmed. Certain techniques such as injecting contrast medium into the ureters, placing a ureteral stent with cold saline, and injecting saline or carbon dioxide into the retroperitoneal cavity all aid in the separation of the ureters and the tumor so no injury is inflicted on the ureters (Arima, Yamakado, Kinbara, et al., 2007). Guidance of the probe also becomes crucial during percutaneous radiofrequency and cryoablations. Navigation of the probes is generally performed under the guidance of computed tomography or magnetic resonance imaging. While ultrasound has the ability to be used in both ablation procedures, it is not recommended during radiofrequency ablations due to the poor image quality caused by steam bubbles that are produced from the vaporization during the procedure (Boss, Clasen, Kuczyk, et al., 2007). Magnetic resonance imaging is preferred during a radiofrequency procedure because of the ability to produce images with high soft tissue contrast (Boss, Clasen, Kuczyk, et al., 2007). During a cryoablation procedure, axial imaging using magnetic resonance and computed tomography is used to monitor the formation of the hypo-dense ice ball (Lehman & Landman, (2), 2008). Being able to visualize this ice ball throughout the procedure insures the total ablation of the tumor (Lehman & Landman, (1), 2008; Lehman & Landman, (2), 2008).

There are a few risk factors of percutaneous ablations, however. One of the risk factors is damage to healthy tissue adjacent to the tumor by the conductance of heat or bitter cold from the probe during the procedures. Although measures are taken to protect surrounding organs and healthy tissue, it is inevitable that some healthy tissue around the tumor will die. Another disadvantage is that the ablated tumors stay in situ, which could possibly cause a relapse (Lehman & Landman, (1), 2008; Boss, Clasen, Kuczyk, et al., 2007). This stresses that the importance of follow-up imaging after a percutaneous ablation is crucial to determine the effectiveness of the procedure. Post-RFA syndrome is a documented complication associated with percutaneous radiofrequency ablations. This occurs in approximately 40 percent of all cases, resulting in flu-like symptoms accompanied by a fever, with symptoms resolving within a couple days (Fergany, 2005). Another disadvantage of percutaneous radiofrequency ablations is that it tends to be more painful than cryoablations (Permpongkosol, Nielsen, & Solomon, 2006). While both radiofrequency ablations and cryoablations are usually performed under conscious sedation, the decreased amount of pain for a cryoablation procedure allows procedures to be done on an outpatient basis, which is more cost effective (Permpongkosol, Nielsen, & Solomon, 2006). However, blood loss during a percutaneous radiofrequency procedure is less than a cryoablative procedure because the heat from the probe cauterizes the blood vessels throughout the ablation (Park, Anderson, & Matsumoto, 2006). In addition, in some cases it takes more than one cryoablation procedure to be fully successful at ablating the tumor (Breen, Rutherford, Stedman, et al, 2007). A study conducted by Breen, Rutherford, Stedman, et al (2007), noted a failure rate of 12.5 percent following the first initial treatment utilizing percutaneous cryoablation. However, after a retreatment, the cancer-free success rate skyrocketed to 97.5 percent. This indicates that patients should be aware that it may take more than one treatment to fully eliminate the renal cell carcinoma. In a multi-institutional study, a total of 271 cases were analyzed and only one death (1.8 percent) was documented which was caused by aspiration pneumonia that was not directly linked to the cryoablation ablation (Breen, Rutherford, Stedman, et al, 2007). The only other major complication involved a patient hemorrhaging to the extensiveness that required a blood transfusion. The most common minor complication following the percutaneous ablative therapies in this study was pain at the probe insertion site which was present in only 9.8 percent of the cases. While there are some disadvantages for percutaneous ablative procedures, the complication rates for them are fairly low.

Objectives

The purpose of this study is to compare the efficacy of percutaneous radiofrequency ablations and percutaneous cryoablations of renal cell carcinoma in terms of the pain associated with each procedure as measured by the amount of conscious sedation required; the amount of post-operative medication required; and the length of time required to perform the procedure.

Research Questions

1. Is there a difference in the amount of intra-operative analgesics administered during a percutaneous radiofrequency ablation and a percutaneous cryoablation?

2. Is there a difference in the length of a percutaneous cryoablation and a percutaneous radiofrequency ablation procedure?

3. Is there a difference in the amount of post operative analgesics administered following a percutaneous cryoablation and a percutaneous radiofrequency ablation?

Definitions

Renal cell carcinoma- a tumor of the kidneys

Cryoablation- procedure in which probes are inserted into a tumor site and argon gases and nitrogen gases are introduced into the core of the tumor causing tumor death

Radiofrequency ablations- a procedure in which probes are inserted into a tumor site and an electrical current is induced into the tumor, heating it up, and eventually causing tumor death

Conscious sedation- an altered state of consciousness induced by anesthesia and pain medications that reduces the amount of pain and discomfort for a patient

Analgesics- medications administered to reduce patient discomfort and pain

Chapter 2

Methodology

This is a retrospective analysis of patient data related to percutaneous cryoablations and radiofrequency ablations for the treatment of renal cell carcinoma. The data was a convenience sample obtained from an existing patient database collected by Riverside Radiology Inc. This study was approved by The Ohio State University Internal Review Board.

The nominal independent variables in this study are the methods used for tumor ablation: radiofrequency ablation and cryoablation. The dependent variables in this study are: the length of time required to complete the procedure, amount of intra-operative analgesics (mg morphine converted dose) administered, and the amount of post-operative analgesics (mg morphine converted dose) administered.

Population and Sample

The sample consisted of 34 patients over the age of 18 who had undergone a renal cell carcinoma percutaneous radiofrequency ablation or a percutaneous cryoablation at Riverside Methodist Hospitals from April 2009 to December 2010. All patients meeting the criteria were originally included in the study, however, when collecting data it was found that there were significantly more radiofrequency ablations performed compared to cryoablations. Thus, in order to allow for an equal comparison, eight of the last radiofrequency ablations were randomly eliminated from the analysis.

Design

This was a retrospective analysis of an existing patient database provided by Riverside Methodist Hospital, Columbus, Ohio. No directly identifiable patient data was obtained. For data analysis, the independent variables were coded as $X_{1=}$ radiofrequency ablations and X_2= cryoablations. The length of time required to complete each procedure was measured in minutes and recorded. To allow analysis as in interval dependent variable, data obtained in reference to the length of procedure was categorized in the following time ranges: 1= 40-49 min; 2= 50-59 min; 3= 60-69 minutes; 4= 70-79 minutes; 5= 80-89 minutes; 6= 90 or more minutes. The amounts of intra-operative and post-operative analgesics administered for each patient were recorded. Since the actual medications utilized varied by patient and interventional radiologist, the analgesic doses were converted to a standard measurement, milligrams of morphine. A research coordinator in the College of Pharmacy at The Ohio State University was consulted and he provided a standardized narcotic converter chart supplied by MedCalc to allow for easier comparison as ratio variables.

Data Analysis

A variation of a Pearson R statistical analysis known as a point bi-serial analysis was conducted to examine the relationship between the two nominal, independent variables (X_1= radiofrequency ablations, and X_2= cryoablations) and the dependent variable, procedure length. A Chi-Square test of significance was used to evaluate the relationship between the two nominal, independent variables ($X_{1=}$ radiofrequency ablations, and X_2= cryoablations) and the dose of intra-operative analgesics and post-operative analgesics administered using a standard converted dose of mg. of morphine. An a priori value = .05 to evaluate the level of significance between all of the variables.

Chapter 3

Results

This study consisted of 34 patients who had a percutaneous ablative therapy performed for the treatment of renal cell carcinoma at Riverside Methodists Hospitals, Columbus, Ohio. Of the 34 procedures that were studied, 19 (55.9%) were percutaneous radiofrequency ablations, and 15 were cryoablations (44.1%) (Table 1).

The doses of intra-operative analgesics administered to patients undergoing a radiofrequency ablation ranged from 30 mg. morphine to 120 mg. morphine, with a median dose of 60 mg. morphine, and a mean dose of 65.13 mg. morphine. One case required a dose of 120 mg. morphine which slightly skewed the mean. If this patient is not included in the sample, the median dose is remains 60 mg morphine and the mean dose is 62.08 mg. morphine. The doses of intra-operative analgesics administered to patients for a cryoablation ranged from 15-95 mg. morphine with a median dose of 82.5 mg. morphine and a mean dose of 90.55 mg. morphine (Table 3). Although the differences in the administered dose of intra-operative analgesics were not statistically significant, the mean dose of intra-operative analgesics administered during the cryoablation procedures is approximately 30% higher than the analgesic dose required during the radiofrequency ablation procedures, eliminating the outlying value, suggesting that a significant finding may exist when studying a larger sample.

The doses of post-operative analgesics given to patients undergoing a radiofrequency ablation ranged from 0-42.3 mg. morphine with a median of 10 mg. morphine and a mean of 10.86 mg. morphine. The amounts of post-operative analgesics administered to patients receiving a cryoablation ranged from 0-61.5 mg. morphine with a median of 7.7 mg. morphine and a mean of 12.15 mg. morphine (Table 4). There were nine patients in this study that did not receive any post-operative analgesics. Five of the nine underwent a radiofrequency ablation, while the remaining four received a cryoablation procedure.

The length of time required to perform the radiofrequency ablation procedures ranged from 40 to 80 minutes with a median of 59 minutes and a mean of 59.74 minutes. The length of time required to perform the cryoablation procedures ranged from 50 to 150 minutes, with a median of 95 minutes, and a mean of 101.33 minutes (Table 5).

1. Is there a difference in the amount of intra-operative analgesics during a percutaneous radiofrequency ablation and a percutaneous cryoablation? (p=.05)

The dose of intra-operative analgesics administered for all 34 patients was recorded and converted to a standard measurement, milligrams of morphine. A chi-square test of significance was performed to compare the two ablation procedures. Using a prior value of (p=.05) the analysis yielded an $X^2 = 15.651$ (df = 14). Using Table IV of Fisher and Yates: Statistical Tables for Biological and Agricultural and Medical Research, the p=.05 value shows 23.685 as the value for comparison. Since 20.466 is not greater than 23.685, it was found that there is no level of significance between the nominal, independent variables and the amount of intra-operative analgesics (Table 5).

FINDINGS: There was no significant difference in the amount of intra-operative analgesics given during percutaneous radiofrequency ablations and percutaneous cryoablations in the treatment of renal cell carcinoma.

2. Is there a difference in the length of procedure during a percutaneous cryoablation and a percutaneous radiofrequency ablation? (p=.05)

The length of procedure for each of the 34 patients that underwent an ablative therapy for the treatment of renal cell carcinoma was recorded. A point bi-serial analysis was conducted to examine the relationship between the two independent variables and the procedural lengths resulting in R = .719, (df=13). The critical value using a prior value of .05 is .6411 indicating a significance between the two independent variables and the procedure lengths (Table 6). After further analyzing the data, it was found that percutaneous cryoablations took significantly longer to complete compared to percutaneous radiofrequency ablations (Figure 1).

FINDINGS: In regards to the treatment of renal cell carcinoma, the length of a percutaneous cryoablation is significantly longer than a percutaneous radiofrequency ablation.

3. Is there a difference in the amount of post operative analgesics used after a percutaneous cryoablation and a percutaneous radiofrequency ablation? (p=.05)

The dose of post-operative analgesics administered was recorded for all 34 patients included in this study and converted to a standard measurement, milligrams of morphine. A chi-square analysis was performed to examine any levels of significance between the two nominal, independent variables (X_1= radiofrequency ablations, X_2= cryoablations) and the amount of post-operative analgesics. The chi-square test of significance yielded a value of 13.76 (df = 5) at an a priori level of (p=.05). Referring table IV of Fisher and Yates: Statistical Tables for Biological, Agricultural and Medical Research, the distribution of X^2 number was 16.92. Since the X^2 value of 13.76 was less than 16.92 (Table 7), there is no significant difference in the amount of post-operative analgesics administered to a patient for a percutaneous radiofrequency ablation or a cryoablation.

FINDINGS: There is no significant difference in the amount of post-operative analgesics given for a percutaneous radiofrequency ablation or cryoablation for the treatment of renal cell carcinoma.

Discussion

In searching for a gold standard in the percutaneous treatment of renal cell carcinoma, this study primarily focused on length of procedure and the doses of intra-operative and post-operative analgesics administered to patients who went through a percutaneous radiofrequency ablation or cryoablation at Riverside Methodist Hospital.

The length of time required to perform each procedure is used to examine the ease and speed of which each of these procedures could be completed. This is an important factor considering that many of the patients receiving a percutaneous ablative therapy for the treatment of renal cell carcinoma have multiple comorbidities. Many of these patients have trouble breathing and cannot withstand lying supine for long periods of time without an overall decline in his/her health status. Minimizing the procedure time allows the patient to be moved to the recovery area more quickly, allowing them to be placed in a more comfortable position to rest and recover. Reducing the procedure time also allows for human resources such as physicians, technologists, and nurses, as well as equipment resources, to be used in a more efficient manner. This increases the availability of all resources to be used to their full potential. A faster procedure allows that patient to get to recovery in a shorter time, allowing them to rest and recover in a better environment.

There are some factors that may affect the promptness at which a percutaneous procedure can be performed, however. Research conducted by Park, Anderson, & Matsumoto (2006) noted that tumors situated anteriorly within the body were difficult to ablate due to fear of injuring a bowel, organ, or ureter. This can infer that if some of these patient's tumors in this study were situated anteriorly or near a vital organ such as small intestines or ureters, the time it takes for that procedure to be completed may be increased due to the location of the tumor within the kidney. The size of the tumor can also have an effect on the time it takes to complete an ablation. According to Arima, Yamakado, Kinbara, et. al (2007), tumors greater than 4 cm in size may require multiple ablation sequences. It can then be inferred that a tumor large in diameter would require multiple ablations and this factor could definitely increase the length of time required to complete the ablation procedure. Due to the limitation of the database utilized for this study, there was no comparison of tumor size and locations.

This study utilized the administered dose of analgesics in mg morphine converted dose during the ablative procedure, and following the ablative therapy as an indication of the pain levels correlated with the two types of ablative therapies. A multi-institutional study conducted by Permpongkosol, Nielsen, and Solomon (2006) demonstrated that percutaneous radiofrequency ablations tended to be more painful to a patient than a cryoablation procedure. However, our study of a convenience sample did not demonstrate a significant difference in the analgesic dose of intra-operative or postoperative analgesics utilized by the type of ablative therapy. Therefore we could not replicate the findings made by Permpongkosol, Nielsen, and Solomon (2006).

Limitations and Further Research

One of the most predominant limitations in this study was the sample size. The small sample size greatly reduces the statistical power in this study. It is recommended that parametric statistics should not be used on a sample size less than 20. It was originally believed that approximately 50 patients would be available for this study in the existing database, allowing a comparison of 25 patients in each ablative procedural category. However, while collecting the data for this study, it was found that the quantity of radiofrequency ablations significantly outnumbered the quantity of percutaneous cryoablations performed at Riverside Methodist Hospital. Therefore a sample of 25 patients undergoing a cryoablation could not be obtained. This limited the total sample available for an equal comparison. The small patient database can be associated to the fact that percutaneous ablative therapies for the treatment of renal cell carcinomas are still a fairly new procedure. Perhaps another study can be conducted in the future as the patient database continues to increase.

Another limitation of this study is that the ablations were performed by more than one interventional radiologist. Perhaps analyzing ablative therapies performed by multiple physicians allows for some bias as to the speed at which a specific physician works and how freely they prescribe medications. In future studies it may be beneficial to include the number of interventional radiologists performing the study as a dependent variable to improve the external validity of the findings.

As mentioned above, the tumor size and location is also another extraneous variable which was not controlled in this study. In future studies it may be beneficial to include tumor size and location as dependent variables.

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Table 1 – Frequency of Ablation Procedures

	Frequency	Percent	Valid Percent	Cumulative Percent
Radiofrequency Ablations	19	54.3	54.3	54.3
Cryoablations	15	42.9	42.9	100.0

Table 2 – Frequency of Intra-operative Analgesics

Procedure	Amount of Intra-operative Analgesics (mg morphine)
RF 1	60
RF 2	75
RF 3	120
RF 4	75
RF 5	45
RF 6	45
RF 7	52.5
RF 8	90
RF 9	75
RF 10	75
RF 11	75
RF 12	30
RF 13	30
RF 14	52.5
RF 15	105
RF 16	60
RF 17	60
RF 18	75
RF 19	37.5
Cryo 1	112.5
Cryo 2	97.5
Cryo 3	75
Cryo 4	90
Cryo 5	60
Cryo 6	60
Cryo 7	45
Cryo 8	15
Cryo 9	105
Cryo 10	60
Cryo 11	45
Cryo 12	90
Cryo 13	135
Cryo 14	195
Cryo 15	82.5

Table 3-Frequencies of Intra-operative Analgesics

	Milligrams of Morphine Converted Dose		
Procedure	**Mean**	**Median**	**Range**
Radiofrequency Ablations	65.13	90.00	30.00-120.00
Cryoablations	90.55	82.50	15.00-95.00

Table 4-Frequencies of Post-operative Analgesics

	Milligrams of Morphine Converted Dose		
Procedure	**Mean**	**Median**	**Range**
Radiofrequency Ablations	10.86	10.00	0.00-42.3
Cryoablations	12.15	7.70	0.00-61.50

Table 5-Frequencies of Lengths of Procedure

	Procedure Lengths in Minutes		
Procedure	**Mean**	**Median**	**Range**
Radiofrequency Ablations	59.74	59	40-80
Cryoablations	101.33	95	50-150

Table 6 – Frequencies of Post-operative Analgesics

Procedure	Amount of Post-operative Analgesics (mg morphine)
RF 1	20.0
RF 2	0.0
RF 3	10.0
RF 4	14.0
RF 5	10.0
RF 6	0.0
RF 7	10.0
RF 8	10.0
RF 9	20.0
RF 10	10.0
RF 11	0.0
RF 12	20.0
RF 13	10.0
RF 14	0.0
RF 15	10.0
RF 16	10.0
RF 17	10.0
RF 18	42.3
RF 19	0.0
Cryo 1	7.7
Cryo 2	23.1
Cryo 3	0.0
Cryo 4	7.7
Cryo 5	10.0
Cryo 6	7.7
Cryo 7	10.0
Cryo 8	0.0
Cryo 9	10.0
Cryo 10	10.0
Cryo 11	30.8
Cryo 12	0.0
Cryo 13	61.5
Cryo 14	3.8
Cryo 15	0.0

Table 7 – Frequencies of Length of Procedure

Length of Procedure

	Length of Procedure (Minutes)						Totals
Procedure	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**	**90 or +**	
RF	3	6	5	2	3	0	19
Cryo	0	1	0	1	5	8	15
Totals	3	7	5	3	8	8	34

Table 8- Chi-Square Test of Intra-operative Analgesics

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.651[a]	14	.335
Likelihood Ratio	20.466	14	.116
N of Valid Cases	34		

a. 30 cells (100.0%) have expected count less than 5. The minimum expected count is .44.

Table 9- Serial Bi-point Test of Significance for Length of Procedure

		Procedure	Procedure Length
Procedure	Pearson Correlation	1	.719
	Sig. 2 (2-tailed)		.000
	N	34	34
Procedure Length	Pearson Correlation	.719	1
	Sig. 2 (2-tailed)	.000	
	N	34	34

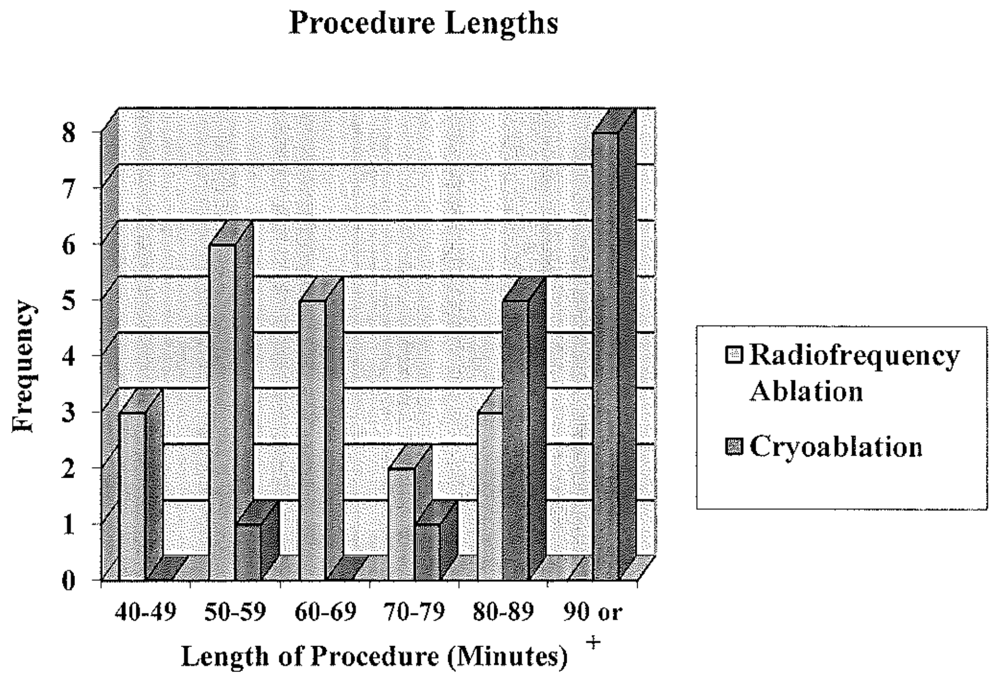
**Correlation is significant at the 0.01 level (2-tailed).

Table 10- Chi-Square Analysis of Post-operative Analgesics

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	13.754[a]	9	.131
Likelihood Ratio	18.249	9	.032
N of Valid Cases	34		

a. 17 cells (85.0%) have expected count less than 5. The minimum expected count is .44.

Figure 1


Procedure Lengths
Frequency
8
7
6
5
4
3
2
1
0
40-49
50-59
60-69
70-79
80-89
90 or +
Length of Procedure (Minutes)
Radiofrequency Ablation
Cryoablation